UNIVERSITY OF CYPRUS

ECTS GUIDE

DEPARTMENT OF PHYSICS

2003-2004

PRODUCTION

Publications Team of the

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University of Cyprus

CONTENTS

SOCRATES PROGRAMME

MAIN OBJECTIVES

The Republic of Cyprus participates in the SOCRATES Programme through a 1998 bilateral agreement with the European Union. Under the terms of this agreement the Government of Cyprus pays an annual subscription of approximately 500,000 EURO to ensure the right of participation, up to this amount, for all eligible educational institutions of Cyprus.

The University of Cyprus, as one of the eligible institutions nominated by the SOCRATES National Agency which, in the case of Cyprus, is the Ministry of Education and Culture, submitted its first Institutional Contract in November 1997.

The objective of the University is to fully participate in European programmes, with the broad aim of extending its international cooperation, and with specific emphasis on the promotion of European ideals in education. The goals set by SOCRATES - those of promoting a European dimension, transparency, mutual trust and recognition of programmes - are ideals which the University of Cyprus fully supports. Through its existing international contacts, the University has already made a first but significant step in contributing to the realisation of these common goals. SOCRATES provides us with a welcome opportunity to make our contribution towards this pan-european effort, a challenge that we take up with eagerness as well as full awareness of the responsibilities that participation involves.

ECTS CREDITS

The European Union's goal of promoting the European dimension in education is facilitated to a large extent through the mobility of students. The ERASMUS Action contributes to this effort by enabling students to learn about, and experience European countries other than their own, their languages, ideals and cultures. Moreover, student exchanges are increasingly becoming a major factor in the development of academic and professional careers.

The future aim of the Union is the recognition, on a pan-european level, of study programmes and qualifications, thus making a reality the vision of an open European educational and vocational training area. The European Credit Transfer System (ECTS) was created and is being promoted to contribute to this goal. It is a tool for establishing and securing transparency, as well as a means of building communication and cooperation among institutions, while simultaneously broadening the educational choice of students.

The system is based on three criteria: **Information** (concerning the programme of study and student performance), **Mutual Learning Agreements** (which are signed by the participating institutions and students), and the use of the **ECTS** (which guarantees transparency with respect to student workload, and which is calculated based on lecture hours, laboratories, workshops, assignments and self-study components of the programme). The system is implemented, and its transparency secured, through the following: the information package, the student application/learning agreement and the transcript of records. The use of ECTS is voluntary and is based on mutual trust and recognition of the academic performance of the collaborating institutions.

The main facilitators of ECTS are the students and academic faculty who believe in its goals and who wish to extend student studies abroad. Full academic recognition is a prerequisite for the mobility of students. This means that the study-abroad period (which includes examinations and other forms of assessment) substitutes for an equal period of home study (which also includes examinations and other forms of assessment), irrespective of the fact that the content of study may be different. In other words, ECTS is based on the full-time workload of the students and is not restricted to the hours of attendance in class.

There are 60 credit units in ECTS, which represent the workload for a full academic year; 30 credits for a semester and 20 credits for a trimester/term. At the University of Cyprus, as a rule, the correspondence between home credits and ECTS is exactly 2:1 (2 European credits: 1 University of Cyprus credit).

The University of Cyprus has implemented the credit system in all departments since its inception, and has established this system on criteria almost identical to that of ECTS.

ELIGIBILITY FOR PARTICIPATION

Students who wish to participate in ECTS must secure in advance the mutual recognition of their credits. Thus, submission of the **Learning Agreement** signed by the host, sending departments and the student is required. Participation in the exchange programme is conditional as follows:

- Students must be citizens of any EU country, the EFTA countries, associated countries in Eastern Europe (Czech Republic, Hungary, Poland, Romania and Slovak Republic), or Cyprus.
- Study at the host University will be free; however, any fees payable to the sending University will still be required.
- Any grant/loan given to students will not be affected by their participation in the ERASMUS exchanges. The period of study abroad should be between 3-12 months.
- First-year students are not entitled to participate in any exchanges.

DEADLINES

Fall Semester 2003-2004

Submission of Application: Beginning of July

Arrival of Students/Registration: End of August / Beginning of September

Spring Semester 2003-2004

Submission of Application: Beginning of November

Arrival of Students/Registration: Third Week of January

SCHOOL OF GREEK LANGUAGE

SOCRATES/ERASMUS students can attend free of charge the intensive Greek language programme that is offered before the beginning of the Fall Semester (August). The intensive programme is of four (4) weeks duration and is intended primarily for exchange students who will be attending courses (of graduate or postgraduate level) at the University of Cyprus.

The intensive programme is offered at both beginner and intermediate levels. Placement of students is based on written examinations.

The courses offered are the following:

(a) Greek language course, which includes familiarisation with the Cypriot dialect, with which the students will have daily contact.

(b) Greek civilisation course, which refers to cultural and social issues facing contemporary Greek society.

(c) Practical exercises in Greek (eg., phonetics and phonology).

(d) Courses of special interest.

Upon course completion, which is followed by both written and oral examinations, a certificate of the School of Greek Language is issued, recording the programme attended, the level, the duration of attendance, the teaching hours and the distinction achieved.

The School of Greek Language is housed at the renovated Axiothea Street Building situated within the city walls.

FURTHER INFORMATION

More details concerning the University of Cyprus, Cyprus itself, the administrative services supporting the SOCRATES Programme and other useful information can be found in the *SOCRATES/ERASMUS Information Guide*, which is published separately. The Guide can be obtained from the Service for Research, International and Public Relations of the University of Cyprus (tel.: +357 22 375115, fax: +357 22 375866).

DEPARTMENT OF PHYSICS

Untill recently, Physics has been offered within the Department of Natural Sciences. This Department has operated since the commencement of the University and incorporated the disciplines of Physics and Chemistry.

An important development for the concentration in Physics is the separation of the Department into two separate departments of Physics and Chemistry, that materialised recently.

There are eleven (11) faculty members in the Physics Concentration; three Professors, five Associate Professors (permanent), two Assistant Professors and one Lecturer. There is also a number of Postgraduate Research Collaborators, one Laboratory Technician and one Assistant responsible for the administration of the computer facilities.

The space currently employed by the Physics Department includes three teaching laboratories, three research computer laboratories, four research laboratories and one computer laboratory. In the near future, Physics will be relocated to the University Campus. There are plans for expansion of the, currently under construction space allocated for offices and laboratories, and of the number of laboratories.

The Physics Department offers programmes of study leading to undergraduate and postgraduate degrees in Physics. Special emphasis is given to a balanced Physics education, offered in the classroom and laboratory: teaching is based on lectures and laboratory exercises, and is supplemented by seminars and recitations. Each year an approximate number of 30 students are accepted in the Physics Department. The first students were accepted in the Fall of 1993. In parallel with the undergraduate studies, the postgraduate programme has started and operates normally.

Aim of the Physics Department is to promote scientific knowledge and research in Physics. Basic and Applied theoretical and experimental research is being conducted in the Department. Members of the Department collaborate and participate in international research programmes with research centres and universities abroad. Examples are the University of Athens, Crete and Patras, the Research Centre “Democritos”, the European Centre of Nuclear Research (CERN), the Centre of Basic Heavy Ion Research (GSI) in Darmstadt, Germany, the Polytechnic School of Zurich (ETH) and the Institute Paul Scherrer in Switzerland, the University of Wuppertal and the Research Centre DESY in Germany, the University of Oxford in England, the Universities of Pittsburgh, Cornell, Harvard, MIT and Stanford in the USA, the University of Toronto in Canada and Pisa in Italy, the Italian Institute of Nuclear Physics (INFN), the University of Tokyo and several laboratories of the French CNRS.

Members of the Department also participate in research programmes funded by the European Union. The number of such programmes is expected to increase in the future. At the same time, the Department collaborates with the local and international industry sector and with research centres in Cyprus. The promotion of a wide spectrum of research topics broadens at the same time the teaching curriculum, and brings students in contact with the modern ideas and problems in Physics. At the same time, it is expected to contribute to the development of research and technical infrastructure, and therefore to the financial prosperity of our country.

UNDERGRADUATE DEGREE PROGRAMME

The programme of studies leading to a degree in Physics was offered for the first time in 1993-94 within the Department of Natural Sciences.

All courses of the Degree in Physics correspond to four (4) units (7 ECTS units), with the exception of CHE 151 - Inorganic Chemistry and CHE 551 - Laboratory of Inorganic Chemistry which correspond to three (3) course units (6 ECTS units) each, and of courses offered by other departments.

The courses included in the Physics Syllabus are divided in five (5) categories.

1. Basic or Introductory Courses.
2. Core Courses.
3. Special Courses.
4. Compulsory Courses offered by other departments.
5. Elective Courses.

The Basic or Introductory Courses (to be completed before other courses can be taken), and the Core Courses are required. They cover the largest spectrum of knowledge that is essential for a contemporary Physicist. In the third year the students begin to attend a number of elective courses; these courses aim to provide specific knowledge, which will be of assistance in the Diploma Thesis that students pursue in their last two semesters of studies.

The Physics Syllabus also includes required courses offered by other departments, such as the Department of Mathematics and Statistics, and the Department of Foreign Languages.

Finally, the Physics Syllabus is supplemented by elective courses offered by other departments. These are chosen by the student in consultation with his academic advisor.

Table of Undergraduate Courses

(1) Basic or Introductory Courses

Code	Course Title
PHY 111	General Physics I
PHY 112	General Physics II
PHY 113	General Physics III
PHY 145	Computational Methods in Physics
CHE 151	Inorganic Chemistry
CHE 551	Laboratory Chemistry I
PHY 511	Laboratory Physics I
PHY 512	Laboratory Physics II
PHY 513	Laboratory Physics III

(2) Core Courses

Code	Course Title
PHY 211	Classical Mechanics
PHY 221	Mathematical Methods of Physics I
PHY 222	Mathermatical Methods of Physics II
PHY 225	Quantum Mechanics I
PHY 226	Quantum Mechanics II - Atomic Physics
PHY 231	Electromagnetism I
PHY 235	Electromagnetism II - Special Theory of Relativity
PHY 241	Statistical Physics

(3) Specialised Courses

Students must take 9 specialised courses:

Group A

Students must take 2 of the following laboratory courses:

PHY521 - Advanced Laboratory Physics I
PHY522 - Advanced Laboratory Physics II
PHY341 - Electronics

Group B

Students must take 4 of the following:

PHY 301 - Solid State Physics
PHY 321 - Nuclear Physics
PHY 331 - Particle Physics
MAS 006 - Complex Analysis
PHY 347 - Computational Physics

In addition students must choose 3 of the following:

PHY 315 - Biophysics
PHY 335 - Theoretical Physics
PHY 351 - Advanced Atomic Physics and Molecular Physics
PHY 345 - Electronic Systems
PHY 305 - Cosmology and General Theory of Relativity
PHY 411 - Project I
PHY 412 - Project II
Any course not taken from Group A
Any course not taken from Group B

(4) Compulsory Courses from other Departments

- Foreign Language (2 courses, 4 ECTS each)
- Mathematics (2 courses, 7 ECTS each): MAS 004, MAS 005

The two courses from the Department of Mathematics and Statistics will be specifically designed to satisfy the math requirements of physics students as determined by the Department of Physics.

(5) University Electives

Students are required to complete 24 ECTS of University Electives outside of their main area of studies.

Final Year Project

The final year project has a special role to play in all the degree programmes of the Department. Each student works under the close supervision of a member of the academic staff of the Department, concentrating on a specialised topic, which he chooses from a list. While carrying out the project, the student learns to search and study the relevant literature, to present seminars to his fellow students in a clear and concise way, and to record and report conclusions. Many of the projects will be experimental in nature. Whereas the final year project work does not have to be original, the Department expects the more capable students to be involved in the research programmes of their supervisors.

Courses offered to Students of other Departments

The Department offers the following courses to students registered in other Departments:

PHY 011	Modern Physics for Poets	(Fall semester)
PHY 012	Physics and Applications	(Spring semester)
PHY 101	Principles of Physics	(Fall semester)
PHY 102	Physics for Chemists	(Fall Semester)
PHY 131	General Physics I: Mechanics and Waves and Thermodynamics	(Fall Semester)
PHY 132	General Physics II: Electricity and Electromagnetic and Optics	(Spring Semester)
PHY 133	Classical and Quantum Mechanics	(Fall Semester)
PHY 531	Basic Experimental Methods	(Spring Semester)

ANALYTICAL PROGRAMME OF STUDY

	ECTS Credits

FIRST YEAR

Fall Semester

PHY 111 General Physics I	7
PHY 511 Laboratory Physics I	7
CHE 151 Inorganic Chemistry I	6
CHE 551 Chemistry Laboratory I	6
MAS 004 Mathematics I	7

Spring Semester

PHY 112 General Physics II	7
PHY 512 Laboratory Physics II	7
MAS 005 Mathematics II	7
PHY 145 Computational Methods in Physics	7

SECOND YEAR

Fall Semester

PHY 113 General Physics III	7
PHY 513 Laboratory Physics III	7
PHY 231 Electromagnetism I	7
PHY 221 Mathematical Methods of Physics I	7

Spring Semester

PHY 211 Classical Mechanics	7
PHY 235 Electromagnetism II	7
PHY 222 Mathematical Methods of Physics II	7
PHY 225 Quantum Mechanics I	7

THIRD YEAR

Fall Semester

MAS 006 Complex Analysis	7
PHY 226 Quantum Mechanics II	7
PHY 241 Statistical Physics & Thermodynamics	7
PHY 347 Computational Physics	7

Spring Semester

PHY 521 Advanced Laboratory Physics I	7
PHY 312 Atomic & Molecular Physics	7
PHY 301 Solid State Physics	7
PHY 321 Nuclear Physics	7

FOURTH YEAR

Fall Semester

PHY 411 Diploma Thesis I	7
PHY 331 Physics of Elementary Particles	7
PHY 522 Advanced Laboratory Physics II	7
PHY 315 Biophysics	7

Spring Semester

PHY 411 Diploma Thesis II	7
PHY 305 Cosmology and Theory of General Relativity	7
PHY 345 Electronic Systems	7
PHY 341 Electronics	7
PHY 335 Theoretical Physics	7

DESCRIPTION OF UNDERGRADUATE COURSES

PHY 012 - Physics and Applications

Nicolaos Toumbas

Course Units: 4 / ECTS Credits: 7

Focus: Important ideas in classical and quantum physics with emphasis on comparisons between classical and quantum behavious.

Syllabus:

- Kinematics in one and two dimensions
- Forces and Newton`s laws of motion
- Dynamics of circular motion
- Work and energy
- Simple harmonic motion and the ideal spring
- Waves
- Wave particle duality
- Heisenberg's uncertainty principle
- The wavefunction and probability
- Solutions of the Schrodinger equation for simple systems such as: free particle, particle in a box, harmonic oscillator. Comparisons with classical results
- Tunneling

Bibliography

Hobson,A.. *Physics. Concepts and Connections*. New Jersey: Prentice Hall, 1995.

Bloomfield, L. A. *How Things Work. The Physics of Everyday Life*. New York: John Wiley & Sons, 1997.

Marion, J. B. *Physics and the Physical Universe.* (3rd Ed.) New York: John Wiley, 1980.

Serway, R. A. *Physics for Scientists & Engineers with Modern Physics*. Vos I, II, III. Greek translation by L. K. Resvanis. Saunders College Publishing, 1990.

Cutnell, J. D., K. W. Johnson. *Physics.* New York: John Wiley & Sons, 1992.

PHY 101 - Principles of Physics

Nicolaos Toumbas

Course Units: 4 / ECTS Credits: 7

This course aims at familiarising students with a non-Physics concentration with some of the traditional and modern physics ideas. It gives emphasis on a non-mathematical approach.

Syllabus

- Classical Physics: Mechanics; uniform and accelerated linear motion; non linear motion; Newton's laws and inertial frames; free fall; momentum conservation; the center of mass; energy conservation; rotational motion; gravity.
- Modern Physics: Photoelectric effect; the wave-particle duality in the microscopic world; the double-slit experiment; electron diffraction; the uncertainty principle; the wave function. Atomic nucleus and radioactivity; nuclear fission and fusion; nuclear reactors. Elements of special relativity; Michelson-Morley experiment; postulates of special relativity; relativity of space and time; simultaneity; the twin paradox; mass-energy equivalence. Equivalence of accelerated frames of reference and gravitational fields; bending of light by gravity; Gravity and geometry; motion of Mercury.

Bibliography

Hewitt, P. *Conceptual Physics.* Harper Collins. Also in Greek translation. University of Crete Press.

Hobson, A. *Physics, Concepts and Connections*. Prentice Hall, 1995.

Epstein, L. *Relativity visualized*. (Greek translation, editions Katoptron).

Lightman. *Great Ideas in Physics.* McGraw Hill, 1992.

PHY 111 - General Physics I

Haralambos Panagopoulos

Course Units: 4 / ECTS Credits: 7

This course is the first in a series of 3 introductory semester courses, which aim at an understanding of the basic concepts and principles of Physics. These courses cover a wide spectrum of classical and modern Physics and provide the necessary background for the more specialised courses. PHY 111 is taught in co-ordination with a laboratory class and relies heavily on exercises and problem solving.

- Physical quantities and measurement units, numerical approximations, vectors, coordinate systems.
- Motion in one and more dimensions, velocity and acceleration.
- Forces, Newton's laws, circular motion, reference frames.
- Work, mechanical energy and its conservation, momentum, center of mass.
- Torque, angular momentum, moment of inertia.
- Oscillations, elastic deformations, pendulum.
- Universal gravitation, Kepler's laws, Newton's law of gravity.
- Fluid mechanics: Density, pressure, buoyancy. Dynamics of fluids, Bernoulli's equation.
- Special Relativity: Speed of light, the Michelson-Morley experiment, Einstein's principle, Lorentz transformations.

Bibliography

Ohanian, H. C. *Physics*.

Taylor ,E. F., J. A. Wheeler. *Spacetime Physics*.

Berkeley Physics Course. Volume I: Mechanics

Kleppner, D., R. J. Kolenkow. *An Introduction to Mechanics*.

PHY 112 - General Physics II

Constantinos Christofides

Course Units: 4 / ECTS Credits: 7

Electricity and Electromagnetism

- Short Historical Review
- Electric Fields
- Gauss`s Law
- Electric Potential
- Capacitance and Dielectrics
- Current and Resistance
- DC Electrical Circuits
- Magnetic Fields
- Sources of Magnetic Field
- Faraday's Law
- Induction and Inductors
- AC Electrical Circuits

Thermodynamics

- Introduction
- Heat and the First Law
- The Second Law, Engines, Refrigerators and Entropy.

Bibliography

Serway, R.A. *Physics for Scientists and Engineers*. Greek Translation: L Resvanis, 1990.

Μαθήματα Φυσικής Πανεπιστημίου Berkeley. Greek Translation: ΕΜΠ.

Alonso, M., E.J. Finn. *Fundamentals University Physics*. 1967. Greek Translation: L. Resvanis.

Halliday, D., R. Resnick. *Physics*. Greek Translation: Pnevmatikos-Peponides, 1974.

PHY 113 - General Physics III

Constantia Alexandrou

Course Units: 4 / ECTS Credits: 7

A brief Historical Introduction.

Waves:

- Wave propagation: Wave equation, General form of progressive waves in one and three dimensions, Principle of superposition, Stationary waves;
- Transverse waves on strings: The governing equation, Kinetic and potential energies, Initial conditions, normal modes, energies of normal modes;
- Longitudinal waves: Waves along a bar, normal modes, Sound waves (Doppler effect, Beats), Phase and group velocity;
- Electromagnetic waves: Maxwell's equations, non-conducting media and the wave equation, speed of light,

Doppler effect for light.

Geometrical optics:

- Introduction;
- Huygen's Principle, Fermat's principle; (b) reflection and refraction: Plane waves on planes surfaces, Spherical waves: plane and spherical surfaces, thin lenses, optical instruments.
- Interference: Conditions for interference, Coherence, Young's experiment, Michelson's Interferometer, Michelson's and Morley's experiment, Interference from thin films, multiple-beam interference and applications, Rayleigh's resolution criterion.
- Diffraction: Fraunhofer diffraction, single slit, double slit, resolving power, diffraction grating, X-ray diffraction, Bragg's law.
- Polarization: Introduction, Polaroid, Malus' law, Polarization from reflection, Brewster's law, double diffraction, production of circular polarized light.
- Light and quantum physics: Blackbody radiation - Planck's quantum hypothesis, photoelectric effect - Einstein's theory of photons, Compton scattering, wave properties of matter, Bohr's theory of the Hydrogen atom, the correspondence principle.

Bibliography

Pain, H.J. *The Physics of Vibrations and Waves*. John Wiley & Sons.

Halliday and Resnick. *Fundamentals of Physics*. John Wiley & Sons.

Alonso,M. and E. J. Finn. *Fundamental University Physics*. Vol. II. Fields and Waves, Addison - Wesley.

Hecht - Zajac, *Optics*, Addison - Wesley.

PHY 145 - Applications of Computers in Physics

Constantia Alexandrou

Course Units: 4 / ECTS Credits: 7

Introductory level course, aiming to familiarize students with the use of computers in solving physics problems. The FORTRAN programming language is used.

- Introduction to the FORTRAN programming language.
- Solution of simple differential equations.
- Radioactive decay
- One- and two-dimensional motion in a uniform gravitational field.
- Motion of a pendulum.
- The solar system. Kepler's laws. The three body problem.
- Rutherford scattering.
- Electrostatic field lines.
- Dynamical behavior of non linear systems, and the logistic map.
- Time evolution of a biological population.
- Solution of non-linear equations.
- Interpolation methods.
- Linear fitting of data from the Physics lab.
- Numerical integration.
- Random number generators.

Bibliography

Etter,.D. *Structured FORTRAN77 for Engineers and Scientists*. Addison-Wesley, 1997.

Kernighan, B. W. and R. Pike. *The UNIX Programming System* (also in Greek translation; Editions Kleidarithmos).

DeVries, P. *A first Course in Computational Physics*. Addison-Wesley, 1993.

Gould, H. and J. Tobochnick. *An introduction to Computer Simulation Methods*. Addison-Wesley, 1996.

De Jong, M.L. *Introduction to Computational Physics*. Addison-Wesley, 1991.

PHY 211 - Classical Mechanics

Stavros Theodorakis

Course Units: 4 / ECTS Credits: 7

Inertial frames and generalized coordinates, Newtonian Mechanics, Lagrange formalism, coservation laws, motion in a central potential, gravitational fields, scattering, small amplitude oscillations, nonlinear oscillations and chaos, noninertial frames of reference, rigid bodies, systems with infinitely many degrees of freedom, Hamilton equations.

Bibliography

Marion - Thornton. *Classical Dynamics of Particles and Systems*. Saunders College Publishing.

PHY 221 - Mathematical Methods of Physics I

Haralambos Panagopoulos

Course Units: 4 / ECTS Credits: 7

Vector Calculus and Applications
- Multiple integrals. Line and surface integrals. Mechanics of rigid bodies. Mass, Center of Mass, Moment of Inertia of bodies having the shape of a line, surface, 3-d region.
- Gradient, divergence, curl. Work and potential energy. The Equations of hydrodynamics. Gravitational field of rigid bodies. Electromagnetic field from current density. Electric/magnetic dipole and quadrupole.
- The theorems of Green, Gauss, Stokes. Conservative forces in nature. Gauss' law in electromagnetism. Flux of a magnetic field. Maxwell's equation in differential and integral form.
- Systems with axial and spherical symmetry.

Fourier Series
- Fourier series and integrals. Convergence criteria.
- Phenomena described by the wave equation. Ways of producing sound, fundamental frequency and harmonics. Time evolution of a vibrating chord.
- Orthogonal functions in Electrostatics, in the Harmonic Oscillator, in the Hydrogen Atom.

Applications of Ordinary Differential Equations in Physics
- From physical laws to the differential equations governing systems in Mechanics, Electromagnetism, Quantum Mechanics in 1 dimension.
- Classification. Solution of first order equations. Existence and uniqueness of solutions.
- Physical systems with linear / nonlinear / chaotic behaviour.
- Conservative systems, driving forces. Analytic methods for solving second order equations. Inhomogeneous terms. Systems of equations. Applications.
- Power series solutions. Critical exponents in Statistical Mechanics.
- Laplace transform. The Dirac function. Impulse and response functions in Physics. Electrical circuits with pulses, discontinuities, multiple loops.
- Introduction to Numerical Methods: Euler, Runge-Kutta. Applications to scattering and to the many-body problem.

Bibliography

Thomas,G.B., R. L. Finney. *Calculus and Analytic Geometry*.

Spiegel, M. *Theory and Problems of Fourier Analysis*.

Boyce, W. E., R. C. Diprima. *Elementary Differential Equations.*

Trahanas, S. *Differential Equations* (Volume I).

PHY 222 - Mathematical Methods in Physics II

Konstantinos Moulopoulos

Course Units: 4 / ECTS Credits: 7

- Boundary Value Problems for Homogeneous Ordinary Differential Equations -Eigenvalue Problem (Sturm-Liouville Theory)
- Linear and Homogeneous Boundary Conditions - The phenomenon of “Quantization” - Liouville equation.
- Self-Adjoint Boundary Conditions: The “Big” Theorems:
  - Reality of Eigenvalues.
  - Orthogonality of Eigenfunctions.
  - Completeness of the set of Eigenfunctions.
- The “small” Theorems:
  - Nodal Theorem.
  - Issues of Degeneracy.
  - A lower bound for Eigenvalues.
  - Symmetry Properties of Eigenfunctions.
  - Fourier Series: the simplest Eigenfunction Expansion.
  - Schrodinger Equation - Schwartzian and its use.
  - Self-Adjoint Eigenvalue Problems and Hermitian Differential Operators - The formalism of Quantum Mechanics.
- Boundary Value Problems for Homogeneous Partial Differential Equations -Generalized Eigenvalue Problem (Method of Separation of Variables)
  - Wave Equation: oscillating string (Hyperbolic Equations).
  - Heat (Diffusion) Equation: heated wall (Parabolic Equations).
  - Laplace Equation: electric field inside a square (Elliptic Equations).

- Wave Equation in polar coordinates: circular drum - Bessel Functions.
- Laplace Equation in spherical coordinates: potential inside a sphere - Legendre Polynomials - Spherical Harmonics.
- Helmholtz Equation in spherical coordinates - Spherical Bessel Functions.
- Problems in infinite or semi-infinite regions: expansion in continuous sets of Eigenfunctions - Dirac's δ-function
- Heaviside θ-function - the concept and use of "Propagator".
- Problems with Inhomogeneous Boundary Conditions and their reduction to Inhomogeneous Differential Equations.

- Boundary Value Problems for Inhomogeneous Differential Equations: The method of Green's Functions
  - Green's Functions for Ordinary Differential Equations - their use in one-dimensional Quantum Scattering.
  - Green's Functions for Partial Differential Equations:
    a. Poisson Equation.
    b. Inhomogeneous Helmholtz Equation - three-dimensional Quantum Scattering and Born Series.
    c. Finite regions: relation between Propagator and Green's Function ("Duhamel Principle") - derivation and use of the Method of Images - application to Electrostatics and Radiation problems.

- General Theory of Partial Differential Equations
  - Well posed problem - Theorem of Cauchy - Kowalewski.
  - Equations of 1st order: method of Characteristics - Applications to Thermodynamics.
  - Linear Equations of 2nd (or higher) order:
    a. Solution techniques for constant coefficients.
    b. Classification (hyperbolic, parabolic, elliptic).
    c. Characteristic curves - Reduction to canonical forms - General behavior of solutions within each class.
    d. Applications to fundamental equations of Mathematical Physics.

- Nonlinear Equations: Shock Waves - Solitons - Bifurcation Theory.

- Applications of Complex Variables to Physical Problems
  - Complex plane - The "phase" in Physics: Electric circuits and Wave Theory.
  - Functions of a complex variable: electron in a magnetic field - Landau levels - Angular Momentum in the complex plane.
  - Analyticity - Cauchy-Riemann conditions: application to two-dimensional irrotational fields.
  - Multivalued functions - branch points - branch cuts - Riemann Surfaces: application to Quantum Hall Effect.
  - Contour Integrals - Cauchy-Goursat theorem - Cauchy integral formulas: Kramers-Kronig dispersion relations and Principle of Causality.
  - Gauss Theorem for mean values - Maximum Modulus Principle and related theorems: Harmonic properties in Electrostatics.
  - Taylor Series - Laurent Series - Analytic Continuation - Residues - Singularities: Quantum Scattering Theory - physical interpretation of Poles, Residues and Riemann Surfaces in Bound States and "Resonances".
  - Calculation of real definite integrals - Jordan's Lemma - Improper Integrals - Cauchy Principal Value - Pole displacement: application to Green's Functions in Quantum Scattering problems.
  - Summation of Series with Residue Calculus: application to Many-Body Theory - Matsubara sums and BCS superconductivity.
  - Conformal Mapping and its application to Fluid Flow, Electrostatics and Heat.
  - Inverse Laplace Transform.
  - Asymptotic analysis: the Steepest Descent Method.

Bibliography

Arfken, G. and H. Weber. *Mathematical Methods for Physicists*. Academic Press, 1995.

Bergados, I. *Mathematical Methods in Physics* (in Greek). vol.I and II, Ioannina, 1998.

Traxanas, S. *Differential Equations* (in Greek). Crete, 1995.

Strauss, W. A. *Partial Differential Equations, An Introduction*. J. Wiley, 1992.

Churchill, R., and J. Brown. *Complex Variables and Applications*. 1993.

PHY 225 - Quantum Mechanics I

Spiros Skourtis

Course Units: 4 / ECTS Credits: 7

- The Schroedinger equation and the wave function.
- Introduction to: the statistical interpretation, wavefunction normalization, momentum/position and Hamiltonian operators, Heisenberg's uncertainty principle.
- Stationary states.
- One dimensional potentials.
- Infinite square well.
- Harmonic oscillator.
- Free particle.

- Delta function potential.
- Finite square well.
- Hilbert space formalism.
- Operators/commutation relations.
- Generalized statistical interpretation and uncertainty principles.
- Three dimensional potentials.
- Hydrogen atom.
- Angular momentum.
- Spin.

Bibliography

Griffiths, D. J. *Introduction to Quantum Mechanics*. Prentice Hall, 1995. Translation in Greek by Prof. Stavros Theodorakis who taught this course before me.

Trahanas, S. *Quantum Mechanics*. Vols 1 & II. Iraklio: University of Crete Press, 1985.

PHY 226 - Quantum Mechanics II

Stavros Theodorakis

Course Units: 4 / ECTS Credits: 7

Angular momentum and spin, composition of angular momenta, identical particles, periodic table, time independent perturbation theory, variational method, time dependent perturbation theory, radiation, Aharonov-Bohm, measurement theory, basic ideas of atomic physics.

Bibliography

Griffiths, D. J. *Introduction to Quantum Mechanics*. Prentice Hall.

PHY 231 - Electromagnetism I

Haralambos Tsertos

Course Units: 4 / ECTS Credits: 7

Introduction:
- The Fundamental Theorem for Gradients
- The Fundamental Theorem for Divergences (Gauss or Green Theorem)
- The Fundamental Theorem for Curls (Stokes Theorem)

Electrostatics:
- The Electrostatic Field ( )
- Divergence and Curl of
- Electric Potential V
- Work and Energy in Electrostatics
- Conductors

Special Techniques for Calculating Potentials:
- Laplace's and Poisson's Equations
- Boundary Conditions and Uniqueness Theorems
- The Method of Images
- Separation of Variables
- Multiple Expansion

Electrostatics Fields in Matter:
- Polarization
- The Field of a Polarized Object
- The Electric Displacement
- Linear Dielectrics

Magnetostatics:
- The Magnetic Field ( )
- The Lorentz Force Law
- The Biot-Savard Law
- The Divergence and Curl of
- Magnetic Vector Potential ( )

Magnetostatic Fields in Matter:
- Magnetization
- The Field of a Magnetized Object
- The Auxiliary Field
- Linear and Nonlinear Media

Electrodynamics:
- Electromotive Force
- Faraday's Law
- Complete set of Maxwell's Equations in Vacuum and Inside Matter
- Coulomb and Lorentz Gauge Transformations
- Energy and Momentum in Electrodynamics
- Poynting's Theorem

Electromagnetic Waves:
- The Wave Equations
- Propagation of Electromagnetic Waves Through Empty Space and Linear Media

Bibliography

Griffiths, David J. *Introduction to Electrodynamics*. Prentice-Hall International Editions.

Griffiths, David J. *Introduction to Electrodynamics*. Vol. I, II. Greek Translation. Greece: University of Crete, (Main Textbook).

Schwartz, M. *Principles of Electrodynamics*. Greek Translation. Greece: Thessaloniki, 1979.

Lorrain, Paul and Dale Corson. *Electromagnetic Fields and Waves*. W.H. Freeman and Company Editions.

Jackson, J.D. *Classical Electrodynamics.* New York: John Wiley and Son, 1962. (Classical Textbook, but rather for an advanced level).

PHY 235 - Electromagnetism II - Special Relativity

Panos Razis

Course Units: 4 / ECTS Credits: 7

Electromagnetic Waves

Maxwell Equations in Vacuum and in Matter, Wave Equation, Waves in 1 Dimension, Transverse and Longitudinal Waves, Linear and Circular Polarisation, Boundary Conditions

Electromagnetic Waves in Non-Conductive Media

Electromagnetic Waves in Non-Conductive Media, Energy and Momentum of the Electromagnetic Field, Poynting Vector, Intensity of Electromagnetic Waves, Reflection and Transmission of Electromagnetic Waves, Boundary Conditions, Perpendicular and Side Incidence, Fresnel Equations, Total Reflection, Brewster Angle, Reflection and Transmission Coefficients

Electromagnetic Waves in Conductors

Continuity Equation, Wave Equations with Damping, Ideal, Good and Bad Conductors, Wave Properties, Boundary Conditions

Dispersion

Electromagnetic Properties of Materials, Dispersion, Phase and Group Velocity, Polarisation in Non-Conducting Media, Anomalous Dispersion, Cauchy Equation, Free Electrons in conductors, Conductivity, Variations of the Damping Coefficient and of the Index of Refraction

Electromagnetic Radiation

Non-Homogeneous Wave Equation, Lorentz Gauge, Static and Non-Static Case, Retarded and Advanced Potentials, Radiation of Electric and Magnetic Dipole, Corresponding Strength of the Electric and Magnetic Field, Mean Radiated Power and Energy

Symmetries and Conservation Laws

Symmetries in Physical Laws, Translation and Rotation, Time Reversal, Space Inversion, Relative Motion, Motion of Reference Systems with a Constant Velocity, Galilean Transformations, Accelerated Frames of Reference, Situation Before the Special Theory of Relativity

Special Theory of Relativity

Principles of Special Theory of Relativity, Unified Description of Matter-Energy, Einstein's Box, Rest Mass, Energy and Momentum, Propagation of Light, Determination of the Speed of Light, Aberration, Ether, Fizeau and Michelson-Morley Experiments, Fresnel's Resistance Coefficient

Lorentz Transformations

Simultaneous Events, Lorentz Transformations, Spacetime Invariant Quantities, Spacetime Distance between Events, Length Contraction, Proper Length, Time Dilation, Proper Time, Synchronizing Watches, Minkowski Diagram, Cosmic Lines, Light Cone, Transformation of Velocities, Transformation of Accelerations, Transformation of Angles

Doppler Effect

Regular and Relativistic Doppler Effect, The Satellite Problem, Artificial Rotation of an Object, Twin Paradox and its Interpretation

Relativistic Dynamics

Elastic Collisions, Conservation of Energy and Momentum, Absorption and Emission of Photons, Moessbauer Effect, Pair Production, Scattering, Threshold Production of Particles, Particle Decays, Compton Scattering, Energy-Momentum Transformations, Transformation of Forces

Covariant Formulation

Four-Vectors, Covariant and Contravariant Vectors, Dot Product and Magnitude of Vectors, Tensors, Metric Tensor, Four-Gradient, Four-Velocity and Four-Momentum

Classical Electrodynamics

Principle of Minimum Action, Euler-Lagrange Equations, Generalized Momentum, Lorentz Force, Gauge Transformations, Electromagnetic Field Tensor, Transformation of Electromagnetic Field, Maxwell Equations, Current Four-Vector, Continuity Equation, Equation of Motion of Electromagnetic Field.

Bibliography

PHY 241 - Thermodynamics and Statistical Mechanics

Georgios Archontis

Course Units: 4 / ECTS Credits: 7

Thermodynamics.

- Basic definitions.
- Definition of systems; Intensive and extensive variables; Zeroth law; Kinetic theory of the ideal gas; Pressure, work and chemical potential; Heat and heat capacity; Reversible and irreversible transformations.
- Laws of Thermodynamics.
- First law; Carnot cycle; Entropy and the second law; Euler equation; Gibs-Duhem relation; Thermodynamic engines; Gibbs phase rule; Clausius-Clapeyron equation.
- Thermodynamic potentials.
- Entropy and Energy; Legendre Trnsformations; Helmholtz Free energy; Enthalpy; Gibbs Free energy; Grand canonical potential; Maxwell relations.

Statistical Mechanics.

- Phase space and entropy.
- Phase space. Statistical mechanical definition of entropy; Entropy of ideal gas and the Gibbs paradox; Quantum-mechanical counting of microstates.
- Ensembles.
- Microcanonical ensemble and examples; Canonical ensemble and examples (the ideal gas, the harmonic oscillator; the earth atmosphere). Relation of microcanonical and canonical ensemble; Equipartition theorem; Heat capacity of solids (Einstein and Debye models); Paramagnetism.
- Quantum Statistical mechanics.
- The quantum ideal gas; The photon gas and black-body radiation; Bose-Einstein and
- Fermi-Dirac statistics; Free-electron gas; Bose-Einstein condensation.

Bibliography

Carrington, G. *Basic Thermodynamics*. Oxford University Press, 1995.

Trikalinos, C. *Molecular Physical Thermodynamics.* (in Greek).

Mandl, F.*Statistical Physics.* (translated in Greek, Eds, Pnevmatikos).

Ikonomou, E.N. *Problems in Statistical Physics and Thermodynamics.* (in Greek). University of Crete Press.

Baierlein, R. *Thermal Physics*. Cambridge University Press, 1999.

Greiner, W., L. Neise and H. Stoecker. *Thermodynamics and Statistical Mechanics*. Springer Verlag, 1995.

PHY 301 - Solid State Physics

Konstantinos Moulopoulos

Course Units: 4 / ECTS Credits: 7

General Introduction: Condensed Matter Physics

Crystal Structures

- Crystallography.
- X-Ray Diffraction - Bragg's law - Laue conditions.
- Reciprocal Lattice - Brillouin zones.
- Quasicrystals.
- Types of crystal binding - Cohesive Energy.

Lattice Dynamics

- Classical Lattice Oscillations - Dispersion Relations.
- Density of States.
- Quantum Theory of the Harmonic Lattice: Phonons.
- Lattice Specific Heat: Einstein and Debye models.
- Role of the Unharmonicity: Thermal Expansion and Thermal Conductivity.

Electronic Properties: Free Electrons

- Free Electron Model in metals.
- Specific Heat of a Free Fermion Gas.

- Transport Properties:
  a. Electric and Thermal Conductivity: Wiedemann-Franz Law.
  b. Hall Effect.
  c. Cyclotronic Resonance.

Electronic Properties: Energy Bands and Correlations
- Energy Band Theory - Bloch's Theorem.
- Nearly Free Electron Approximation.
- Tight-Binding Approximation (or LCAO Method).
- Exact solutions in Kronig-Penney type models - Transfer Matrix Method -

Landauer Resistance.
- Metals - Insulators - Semiconductors.
- Semiclassical Dynamics of Bloch Electrons: Bloch Oscillations in Superlattices - Holes - Effective Mass.

Mott's Metal - Insulator Transition.

The meaning of "Nesting" in Fermi Surfaces and "Peierls Instability": Charge-Density-Waves (CDW) - Spin-Density-Waves (SDW).

Correlations and the Wigner Crystal.

Semiconductors
- Intrinsic behavior.
- Doping - Extrinsic Semiconductors.
- Transport Properties and Optical Properties: Excitons.
- Far from Equilibrium - Semiconducting Devices.

Special Topics
- Macroscopic Quantum Phenomena: Superconductivity.
- Quantum Hall Effect.
- Dielectric Function: Screening - Plasma Oscillations.
- Determination of Fermi Surfaces - de Haas-van Alphen Effect.
- Magnetic Properties - Hubbard Model.

Bibliography

Hook, J. R. and H. E. Hall. *Solid State Physics*. J. Wiley, 1991.

Kittel ,C. *Introduction to Solid State Physics*. J. Wiley, 1996 (Greek translation).

Levy, R. A. *Principles of Solid State Physics*. Academic Press, 1977 (Greek translation).

Myers, H. P. *Introductory Solid State Physics.* Taylor and Francis, 1990.

Ashcroft, N. W. and N. D. Mermin. *Solid State Physics*. Holt-Saunders, 1976.

PHY 305 - Cosmology and General Relativity

Nicolaos Toumbas

Course Units: 4 / ECTS Credits: 7

- Introduction: Observations leading to General Relativity. Phenomena studied by Cosmology.
- Spacetime in General Relativity. Geodesics and gravitational potential.
- Stress-energy tensor. Riemann curvature tensor. Einstein equations. The Schwarzschild solution.
- On 5 classic tests of General Relativity: Calculation and experimental verification.
- Precession of perihelia.
- Bending of light rays.
- Spectral shift.
- Delay in radar sounding.
- The "geodesic" phenomenon.
- Black holes: Schwarzschild, Kerr. Their thermodynamics, evaporation. Observations from Cygnus I.
- Gravitational radiation. Gravitons.
- Linear perturbation of the Einstein equations.
- Detectors of gravitational radiation emanating from the galactic cluster in Virgo.
- Power of gravitational radiation emitted by pulsars.
- The expanding Universe.
- The Universe as a perfect fluid. Robertson-Walker metric. Friedmann models.
- Event horizon. Particle horizon.
- Big Bang: The evidence for it. Physical processes at various stages of the Universe. Dark matter.
- Elements of Astrophysics.
- Hydrostatic equilibrium in stars.

- Types and characteristics of galaxies. Quasars. Mass deficit.
- Temperature and luminosity. Evolution of stars. The main sequence.
- Stellar fuel. The CNO cycle.
- Red giants. White dwarfs. Neutron stars. Pulsars. Novae and Supernovae.

Bibliogaphy

Foster, J. J., D. Nightingale, *A Short Course in General Relativity.* Longman.
Schutz, B. F. *A First Course in General Relativity.* Cambridge U. Press.
Berry, M. *Principles of Cosmology and Gravitation.* Institute of Physics Publishing.
Shu, F. *The Physics of Astrophysics*. Vol. I. Univ. Science.

For in-depth reading

Weinberg, S. *Gravitation and Cosmology: Principles and Applications of General Relativity*. Wiley.
Peebles, P.J.E. *Principles of Physical Cosmology.* Princeton U. Press.
Misner, C., K. Thorne, J. A. Wheeler. *Gravitation.* W. H. Freeman.
Kolb, E., M. Turner. *The Early Universe.* Addison - Wesley.

PHY 312 - Atomic and Molecular Physics

Spiros Skourtis

Course Units: 4 / ECTS Credits: 7

Atomic Physics
- Angular momentum and spin
- The hydrogen atom
- Approximate methods for the solution of the Schrodinger equation
- Atomic electronic structure and spectra

Molecular Physics
- The Born-Oppenheimer approximation
- The chemical bond
  - The H_2^+ molecular ion
  - The H_2 molecule
  - Valence-bond and molecular-orbital theories
- The Hartree-Fock method
- Molecular electronic structure and spectra

Bibliogaphy

Haken, H., H. C. Wolf. *The Physics of Atoms and Quanta*, Springer, 1996.
P.W., Atkins, *Molecular Quantum Mechanics*, Oxford University Press 1986 (2nd edition).
D.J., Griffiths, *Introduction to Quantum Mechanics*, Prentice Hall, 1995. Translation to Greek by S. Theodorakis.

PHY 315 - Biophysics

Spiros Skourtis

Course Units: 4 / ECTS Credits: 7

Focus: Molecular biophysics with emphasis on proteins.
- Brief introduction to the central dogma of molecular biology.
- Brief description of proteins, nucleic acids, lipids, carbohydrates, and of their biological functions.
- Protein structure.
- Protein dynamics.
- Examples of protein function.
- Intramolecular and intermolecular forces that determine structure, dynamics, and functions of proteins.
- Born-Oppenheimer approximation.
- Description of chemical reactions in terms of energy surface.
- Enzyme kinetics and actions.
- Allosteric mechanisms.

- Two-state systems in quantum mechanics.
- Landau-Zener transition probability (explanation of Landau-Zener probability to election transfer).

Bibliography

Chamodrakas, S. *Topics in Molecular Biophysics*. Symmetria Publishing Co, Athens, 1993.

Nosal, R., H. Lecar. *Molecular and Cell Biophysics.* Addison Wesley, 1991.

Billing, G.D., K. V. Mikkelsen. *Introduction to Molecular Dynamics and Chemical Kinetics*. New York: John Wiley & Sons, 1996.

Tinoco Jr., I., K. Sauer, J. C. Wang. *Physical Chemistry - Principles and Applications in Biological Sciences*. New Jersey: Prentice Hall, 1995.

Creighton, T. E. *Proteins - Structures and Molecular Properties*. New York: W. H. Freeman and Co, 1993.

PHY 321 - Nuclear Physics

Haralambos Tsertos

Course Units: 4 / ECTS Credits: 7

- Introduction
- Nuclear Properties
- Nuclear Models
- Radioactive Decay
- Alpha Decay
- Beta Decay
- Gamma Decay
- Nuclear Reactions and their Kinematics
- Nuclear Fission and Nuclear Fusion
- Nuclear Astrophysics

Bibliography

Krane, Kenneth S. *Introductory Nuclear Physics.* John Wiley & Sons, (Main Textbook).

Cottingham, W.N., and D.A. Greenwood. *Introduction to Nuclear Physics*, Greek Translation.

Patel, S.B. An *Introduction to Nuclear Physics.* John Wiley & Sons.

Charalambous ,St. *Introduction to Nuclear Physics.* University of Thessaloniki, Greece.

Fermi, E. *Nuclear Physics*. Original course notes compiled by the University of Chicago.

Blatt, J.M., and V.F. Weisskopf. *Theoretical Nuclear Physics,* Springer-Verlag (Classical Textbook, but rather for an advanced level).

PHY 331 - Particle Physics

Panos Razis

Course Units: 4 / ECTS Credits: 7

Brief Historical Background

Large Scale vs Small Scale, First Rational Attempts to Describe the Structure of Matter, Ancient Greek Philosophers, Chemical Elements, Unification of Electricity with Magnetism, Radioactivity, Atomic Model, Quantum Mechanics, Light: Particles or Waves?, Discovery of Particles

Particles of Matter and Fundamental Interactions

Strong-Electromagnetic-Weak-Gravitational Force, Fundamental Particles of Matter, Interaction Carriers, Uncertainty Principle, Vacuum Polarisation, Screening and Antiscreening, Colour, Asymptotic Freedom, Confinement

Interactions of Particles and Radiation with Matter

Energy Loss Mechanism, Minimum Ionising Particle, δ-Rays, Density Effect, Range, Multiple Scattering, Landau Distribution, Interactions of γ-Rays with Matter (Photoelectic Effect, Compton Scattering, Pair Production), Bremmstrahlung Radiation, Radiation Length, Electromagnetic Showers, Cerenkov Radiation

Particle Detectors and Accelerator Systems

Operational Parameters of Detectors, Scintillation Counters, Cerenkov Detectors, Bubble Chambers, Spark Chambers, Streamer Chambers, Ionisation Chambers, Scattering and Mobility of Ions, Drifting of Electrons, Lorentz Angle, Signal Determination in an Ionization Chamber, Operational Modes of Ionisation Chambers, Proportional Ionisation Chambers, Geiger Mueller Counters, Drift Chambers, Transition Radiation Detectors(TRD's), Semiconductor Detectors, Electromagnetic and Hadronic Calorimetry, Radiation and Interaction Length, Homogeneous and Sampling Calorimeters, Linear and Circular Particle Accelerators

Symmetries, Quantum Numbers and Conservation Laws

Euler-Lagrange Equations, Continuous and Discrete Symmetries, Noether's Theorem, Conserved Currents, Symmetry Generators, Spin, Isotopic Spin, Particle Multiplets, Supercharge, Conservation Rules, Parity(P), Parity Violation in Weak Interactions, Particle Helicities, Charge Conjugation(C), Time Reversal(T), CP and CPT Symmetry, Kaons, Strangeness Oscillations, CP Violation, Unitary Symmetry, SU(2) and SU(3) Representations, Quark Content of Composite Particles

Quantum Electrodynamics

Basic Feynman Diagrams, Global and Local Gauge Transformations, Local Gauge Symmetry, General Properties of Quantum Electrodynamics

Weak Interactions

Brief History of Weak Interactions at Low Energies, Fermi Theory of Beta Decay, V-A Theory, Selection Rules, Cabibbo Angle, CKM Matrix, Manifest vs Hidden Gauge Symmetry, Spontaneous Symmetry Breaking, Higgs Mechanism, Intermediate Vector Bosons, Weinberg Angle, Charged and Neutral Currents, Glashow–Weinberg-Salam Electroweak Theory

Quantum Chromodynamics

Local Gauge Transformations, Gluonic Fields, General Properties of Quantum Chromodynamics, Screening and Antiscreening, Colour, Asymptotic Freedom, Confinement

Unification Theories

Problems of the Standard Model, Grand Unification Theories, SU(5), Extrapolation of Coupling Constants, Proton's Lifetime, sin2θw , Supersymmetry and Supersymmetric Particles

Applications

Areas of Applications Arising from the Studies of Atoms, Nuclei and Fundamental Particles (Telecommunications, Electronics, Computers, Medicine, Archeometry, Energy Production, Industry, New Materials, Applications in other Natural Sciences)

PHY 335 - Theoretical Physics

Haralambos Panagopoulos

Course Units: 4 / ECTS Credits: 7

- Symmetries: Definition, Physical consequences of symmetries, Symmetries in Classical Mechanics, Symmetries in Quantum Mechanics.
- The Heisenberg representation.
- Charges in electromagnetic fields, gauge invariance, invariants of the field, the action function of the electromagnetic field, the energy and momentum tensor.
- Relativistic quantum mechanics: The Klein-Goldon equation, the Dirac equation.
- Scattering theory: Green's functions, Asymptotic states, potential scattering, phase shifts, resonances.

Bibliography

Griffith, David. *Introduction to Elementary Particles*. John Wiley & Sons, Inc., 1987.

Perkins, Donald H. *Introduction to High Energy Physics*. Addison Wesley, 1987.

Kane, Gordon. *Modern Elementary Particle Physics*. Addison Wesley, 1993.

Halzen, Francis, Alan D. Martin. *Quarks & Leptons*. John Wiley and Sons, 1984.

Aitchison, I.J.R., A.J. G. Hey. *Gauge Theories in Particle Physics*. Graduate Student Series in Physics.Institute of Physics Publishing Ltd, 1989.

Βέργαδος, Ι.Δ., Η. Τριανταφυλλόπουλος. *Στοιχειώδη Σωμάτια*. Εκδόσεις Συμεών, 1990.

Ασημακόπουλος, Παναγιώτης Α. *Πυρηνική Φυσική*. Δεύτερος Τόμος. Εκδοτική Παραγωγή: Επτάλοφος Α.Β.Ε.Ε., 1984.

Τσιλιμίγκρας, Παναγιώτης. *Φυσική Στοιχειωδών Σωματιδίων*. Εκδοτικός Οργανισμός: Γρηγόρης Φούντας.

Lee, T.D. *Particle Physics and Introduction to Field Theory*. Contemporary Concepts in Physics. Volume 1. Harwood Academic Publishers, 1981.

Cheng, Ta-Pei, Ling-Fong Li. *Gauge Theory of Elementary Particle Physics*. Oxford Science Publications, 1984.

Commins, E.D., P.H. Bucksbaum. *Weak Interactions of Leptons and Quarks*. 1983.

Okun, Lev Borisovic. *Leptons and Quarks*. North-Holland, 1982.

Additional Bibliography on specialized topics will be provided during the course.

PHY 341 - Electronics

Andreas Othonos

Course Units: 4 / ECTS Credits: 7

The objective of this course is to introduce the students to modern electronics, providing a though comprehensive and practical coverage of electronics devices, circuits and applications. Laboratory experience is an essential part of the course. Most of the lectures will describe how a variety of basic modern electronic elements such as diodes, bipolar junction transistors, filed-effects transistors operate and how to analyze a circuit containing these elements.

Course outline
- DC and AC circuits
- Semiconductors and applications to circuits
- PN junction diodes
- Transistors
- Fill effect transistors
- Digital circuits

In parallel with these lectures there are associated experiments in the above areas, giving the student on hand experience with electronics.

Bibliography

Καρούμπαλου, Κ. και Γ. Φιλοκύπρου. *Μαθήματα Ηλεκτρονικής.*

Nillman, Jacob. *Μικροηλεκτρονική*. Τόμος Α. Arvin Grabel.

Γεωργοπούλου,Χ.Ι. *Ηλεκτρονική*. Τόμος Α. *Βασικά Ηλεκτρονικά Ημιαγωγά Στοιχεία και Κυκλώματα Διακριτικής Μορφής.*

Δεληγιάννης, Θ. Λ. *Ηλεκτρονικά Στοιχεία - Κυκλώματα*. Τόμος Α.

PHY 347 - Computational Physics

Georgios Archontis

Course Units: 4 / ECTS Credits: 7

- Chaotic behaviour of dynamical systems: Introduction, the logistic map, period doubling, universal behaviour, Feigenbaum's constants, the Lorentz model.
- Fractals: Fractal dimension, Geometrical Fractal, Fractals and chaos, Multifractals.
- Numerical solution of partial differential equations: Diffusion equation, Wave equation, Laplace equation, Schodinger equation, Crank-Nicolson method, Convergence criteria for the algorithms.
- Percolation: clusters, critical exponents, Anderson localization.
- Molecular Dynamics Simulations.
- Stochastic Methods: Introduction, Monte Carlo Simulations (Microcanonical and anonical Ensemble), The Ising model.

Bibliography

Gould,H. and J. Tobochnik. *An introduction to computer simulation methods*. Addison - Wesley.

Garcia, A. L. *Numerical methods for Physics*. Prentice Hall.

Koonin, S. E. and D. C. Meredith. *Computational Physics.*

PHY 511 - Physics Laboratory I

Course Units: 4 / ECTS Credits: 7

This is a first year laboratory coarse in physics. It concentrates in giving a new comer in physics the tools to properly collect data and analyze his or her results. This coarse begins with the introduction to error analysis followed by series of experiments, which are designed to take approximately 4 hours for completion.

Theory of error analysis
- Types of errors
- Error propagation with examples
- Gaussian distribution
- List square fit

Experiments
- A simple pendulum
- Hooks Law
- Moment of inertia and angular acceleration
- Coupled Pendulum
- Laws of collision
- Forced oscillations
- Mechanical conservation of energy
- Air Resistance

Bibliography

Παπαγεωργόπουλος, Χ. *Εισαγωγή στα πειράματα Φυσικής*. Εκδόσεις Πανεπιστημίου Ιωαννίνων, 1983.

Φίλης, Ι. Γ. *Εργαστήρια Πειραματικής Φυσικής*. Εκδόσεις Πανεπιστημίου Ιωαννίνων, 1992.

Χαλδούπης, Χρ. *Εργαστηριακές ασκήσεις Φυσικής*. Εκδόσεις Πανεπιστημίου Κρήτης, 1987.

Bevington. *Data Reduction and Error Analysis for the Physical Sciences*. McGraw-Hill, 1969.

Taylor. *An Introduction to Error Analysis*. University Science Books, 1982.

Ασημακόπουλος, Π. Α. *Ηλεκτρομαγνητική Θεωρία και Πρακτική*. Εκδόσεις Πανεπιστημίου Ιωαννίνων, 1984.

Tsoulfanidis, N. *Measurement and Detection of Radiation.* McGraw-Hill Series in Nuclear Engineering.

Serway ,R. *Physics for Scientists and Engineers*. Απόδοση στα Ελληνικά, Λ. Κ. Ρεσβάνη.

Ohanian, *Φυσική*

Alonso-Finn. *Θεμελιώδης Πανεπιστημιακή Φυσική*. Επιμέλεια-Μετάφραση Ρεσβάνη-Φίλιππα.

Σειρά βιβλίων Φυσικής Berkeley, Απόδοση στα Ελληνικά, Εργαστήρι Φυσικής Εθνικού Μετσοβίου Πολυτεχνείου.

Halliday-Resnick. *Φυσική*. Απόδοση στα Ελληνικά, Πνευματικός-Πεπονίδης.

PHY 512 - Physics Laboratory II

Panos Razis

Course Units: 4 / ECTS Credits: 7

Catalogue of Experiments:

- Maxwell Distribution of Velocities
- Heat Capacity of Gases
- Electrolysis
- Falling Ball Viscometer
- Charging of a Capacitor
- Measurement of Magnetic Fields
- Magnetic Moment
- Magnetic Induction
- RLC Circuits
- Radiation - Stefan Boltzmann Law
- Simulation of Electromagnetic Fields

Bibliography

Theory:

Serway, R. *Physics for Scientists and Engineers*. Απόδοση στα Ελληνικά: Λ. Κ. Ρεσβάνη.

Ohanian. *Φυσική*. Απόδοση στα Ελληνικά: Α. Φίλιππα.

Alonso - Finn. *Θεμελιώδης Πανεπιστημιακή Φυσική*. Επιμέλεια-Μετάφραση: Ρεσβάνη-Φίλιππα.

Σειρά βιβλίων Φυσικής Berkeley. Απόδοση στα Ελληνικά: Εργαστήριο Φυσικής Εθνικού Μετσοβίου Πολυτεχνείου.

Halliday - Resnick. *Φυσική*. Απόδοση στα Ελληνικά: Πνευματικός - Πεπονίδης.

Experiment:

Παπαγεωργόπουλος, Χ. *Εισαγωγή στα Πειράματα Φυσικής (Μηχανική-Θερμότητα)*. Εκδόσεις Πανεπιστημίου Ιωαννίνων, 1987.

Πάνος, Κ. *Ασκήσεις Εργαστηρίου Φυσικής*. Εκδόσεις Ιων.

Φίλης, Γ. *Εργαστήρια Πειραματικής Φυσικής*. Εκδόσεις Πανεπιστημίου Ιωαννίνων, 1992.

Χαλδούπης, Χρ. *Εργαστηριακές Ασκήσεις Φυσικής*. Εκδόσεις Πανεπιστημίου Κρήτης, 1987.

Distributions and Error Analysis:

Καραγιάννης, Μ.Ι. *Επεξεργασία, Αξιολόγηση και Παρουσίαση Αναλυτικών Δεδομένων*. Αθήνα, 1987.

Bevington. *Data Reduction and Error Analysis for the Physical Sciences*. McGraw-Hill, 1969.

Taylor. *An Introduction to Error Analysis*. University Science Books, 1982.

Ασημακόπουλος, Π.Α. *Ηλεκτρομαγνητική Θεωρία και Πρακτική*. Εκδόσεις Πανεπιστημίου Ιωαννίνων, 1984.

Tsoulfanidis, N. *Measurement and Detection of Radiation.* McGraw-Hill Series in Nuclear Engineering, 1983.

PHY 513 - Physics Laboratory III

Course Units: 4 / ECTS Credits: 7

Catalogue of Experiments:
- The Vibration of Strings
- Determination of Wavelengths and Frequencies with the Quincke Tube
- Determination of the Velocity of Sound Using Kundt`s Tube.
- Polarization by Quarterwave Places
- Laws of Lenses and Optical Instruments
- Dispersion and Resolving Power of the Prism
- Interference at a Fresnel Mirror
- Measuring the Velocity of Light
- Michelson Interferometer
- Diffraction at a Slit and Double Slit
- Interference at a Mica Plate
- Experiments on Ultrasonics

Bibliography

Παπαγεωργόπουλος, Χ. *Εισαγωγή στα πειράματα Φυσικής*. Εκδόσεις Πανεπιστημίου Ιωαννίνων, 1983.

Φίλης, Ι. Γ. *Εργαστήρια Πειραματικής Φυσικής*. Εκδόσεις Πανεπιστημίου Ιωαννίνων, 1992.

Χαλδούπης, Χρ. *Εργαστηριακές Ασκήσεις Φυσικής*. Εκδόσεις Πανεπιστημίου Κρήτης, 1987.

Bevington. *Data Reduction and Error Analysis for the Physical Sciences*. McGraw-Hill, 1969.

Taylor. *An Introduction to Error Analysis*. University Science Books, 1982.

Ασημακόπουλος, Π. Α. *Ηλεκτρομαγνητική Θεωρία και Πρακτική*. Εκδόσεις Πανεπιστημίου Ιωαννίνων, 1984.

Tsoulfanidis, N. *Measurement and Detection of Radiation*. McGraw-Hill Series in Nuclear Engineering.

Serway, R. *Physics for Scientists and Engineers*. Απόδοση στα Ελληνικά, Λ. Κ. Ρεσβάνη.

Ohanian. *Φυσική*.

Alonso-Finn. *Θεμελιώδης Πανεπιστημιακή Φυσική*. Επιμέλεια-Μετάφραση Ρεσβάνη-Φίλιππα.

Σειρά βιβλίων Φυσικής Berkeley. Απόδοση στα Ελληνικά, Εργαστήρι Φυσικής Εθνικού Μετσοβίου Πολυτεχνείου.

Halliday-Resnick. *Φυσική*, Απόδοση στα Ελληνικά, Πνευματικός-Πεπονίδης.

PHY 521 - Advanced Physics Laboratory I

Andreas Othonos

Course Units: 4 / ECTS Credits: 7

This is the first advanced laboratory coarse in physics. The coarse introduces the student to advance experiments in physics. It allows the student to develop his or her methodology of collecting and analyzing data.

- The Hall effect in p-germanium
- The behavior and study of photocells
- The bandgap of germanium
- The Hall effect in metals
- Spectroscopy of semiconductors
- X-ray diffraction - Bragg scattering of a crystal structure
- A study of microwaves - the behavior of microwaves.
- Advance interferometry - methods and measurements
- The Ar+ ion laser - the study of a gas laser system.

Bibliography

Pankove, Jacques I. *Optical Processes in Semiconductors*. New York: Dover Publication.

Seeger, K. *Semiconductor Physics - An Introduction*. (Solid State Sciences 40), Springer Verlag.

Streetman, Ben G. *Solid State Electronic Devices*. Prentice-Hall.

PHY 522 - Advanced Physics Laboratory II

Haralambos Tsertos

Course Units: 4 / ECTS Credits: 7

Introduction:
- Gauss and Poisson Distributions
- Least Squares Method
- Interaction of Charged Particles with Matter
- Basic Nuclear Electronics

Experiments:
- Measurement of the Specific Charge of the Electron
- Observation of the Zeeman Effect
- Observation of the Electron Spin Resonance
- The Compton Effect
- X-Ray Fluorescence and Moseley’s Law
- Rutherford Scattering
- Spectroscopy of α-Particles
- Spectroscopy of β-Particles
- Spectroscopy of γ-Rays
- The Geiger-Müller Counter

Bibliography

Tsertos, H. *Experimental Physics II*. Comprehensive Students Manuscript. Nicosia: University of Cyprus, 1999. (Main text, in Greek).

Bevington, P. R. *Data Reduction and Error Analysis for Physical Science*. New York: McGraw-Hill Book Company.

Leo, W. R . *Techniques for Nuclear and Particle Physics Experiments*. Berlin, Heidelberg: Springer-Verlag.

Tsoulfanidis, N. *Measurement and Detection of Radiation*. New York: McGraw-Hill.

Melissinos, A. *Experiments in Modern Physics*. Academic Press.

Krane, K. S. *Introductory Nuclear Physics*. New York: John Wiley & Sons.

POSTGRADUATE DEGREE PROGRAMME

GENERAL INFORMATION

Students admitted to the postgraduate programme must complete 30 units (54 ECTS) of postgraduate coursework and must write a dissertation. Twenty of these units (35 ECTS) correspond to 5 compulsory courses (Quantum Mechanics I and II, Electromagnetism, Statistical Physics, Advanced Lab), while the rest correspond to optional special topics. Ph.D. candidates must also pass a qualifying exam by the end of the fifth semester. The Department admitted its first postgraduate students in 1994. Postgraduate courses were first offered in the Fall of 1999.

DESCRIPTION OF POSTGRADUATE COURSES

PHY 625 - Quantum Mechanics I (Graduate level Nonrelativistic Quantum Mechanics)

Konstantinos Moulopoulos

Course Units: 4 / ECTS Credits: 7

Quantum Phenomena

Recent experiments: microcosm, but also Macroscopic Quantum Mechanics.

The Formalism of Quantum Mechanics

Mathematical preliminaries - Dirac formalism: its power, but also its “dangers” - Quantum bits (Qubits) - The Statistical Operator (“Density Matrix”) and its use - Non-Self-Adjointness and Fuzzy operators.

Quantum Kinematics and Dynamics : Symmetries and Generators

Invariance under space-time transformations - derivation of Dynamical variables - Schrodinger and Heisenberg Pictures - Conservation Laws.

Position and Momentum Representations

Applications to one-dimensional problems - Tunneling - Transfer Matrix formulation for extended systems - Quantum Wires and Networks - Propagator and Green’s function - Path Integrals - Applications of Momentum Representation to Diffraction theory and Interferometry - Spatial Periodicity and Bloch’s theorem - The “difficulties” of the Classical limit (Wigner function and Husimi distribution).

Harmonic Oscillator

Algebraic method and formal relation to other quantum systems - Solution in Position, Momentum and Energy Representation - Coherent and Squeezed States and their use in Path Integrals.

Angular Momentum (Orbital and Spin)

Pauli Algebra - Representation Theory of Finite Rotations: Lie Groups and Lie Algebras - Addition of Angular Momenta and Clebsch-Gordan coefficients - Irreducible Tensor Operators and Wigner-Eckart theorem.

Interpretation of Quantum State and the “Quantum Measurement Problem”

Experimental Preparation and Determination of Quantum States - Correlations (Entanglement) in composite systems - Generalized Indeterminacy Relations - Miminum Uncertainty States - Multiple Stern-Gerlach devices - EPR Paradox - Bell’s Inequalities - Aspect’s experiment.

Systems with Bound States - Approximation Methods

Hydrogen Atom (in 3-d, but also in 1-d and 2-d that present special recent interest!) - Perturbation Theories - Variational Methods - Hellmann-Feynman and Virial theorems - Darboux Transformation and Supersymmetric (SUSY) Quantum Mechanics for “Quasi-Soluble” potentials.

Charged Particle in a Magnetic Field - Aharonov–Bohm Effect

Gauge Transformations - Landau levels - Magnetic Translation Group - Particles in different geometries in the presence of a magnetic flux - Quantum Dots in a magnetic field and other Mesoscopic devices - Quantum Chaos.

Time-Dependent Systems

Generalized Spin-Resonance effects in two-state systems - Non-exponential decays and the Spectral Function of a state - “Energy-Time Indeterminacy” - Quantum Beats - “Quantum Zeno Phenomenon (Paradox)” - Time-dependent Perturbation Theory - Time-periodicity and Floquet theorem - Adiabatic approximation: Berry’s phase and its extensive use in all fields of modern Physics.

Elements of Quantum Scattering

Neumann Series and Born Approximation - “Resonances” (Virtual Bound States) - δ-function in D-dimensions and how we deal with infinities like the ones appearing in Quantum Field Theory (Regularization, Renormalization etc.)

Identical Particles - The Formalism of Second Quantization

Experiments that confirm the “Symmetrization Postulate” - Fock space –Wick’s theorem - Representation of operators in Second Quantization and upgrading of our calculation machinery.

Many-Fermion Systems - Correlation and Exchange

He atom and Dynamical Correlations - Exchange in H_2 molecule - Correlations in the Fermi sea - the meaning of vacuum state - Correlation Hole - Hartree-Fock theory and Lindhard function - Cooper pairs and BCS pairing

- Bogolyubov-Valatin transformations to a new vacuum - “Number-Phase Indeterminacy” in Superconductivity.

Quantization of the Electromagnetic Field

Electric and Magnetic Field Operators - Infinities of the zero-point energy - Casimir Effect - Photons - “Number-Phase Indeterminacy” in systems with a variable number of particles.

Topics from Modern Quantum Optics

Coherent and Squeezed states, “Intelligent states”, “Schrodinger Cat states” and their generalizations - Hermitian “Phase Operator” - Rydberg Wavepackets.

Bibliography

The level of the course (but not the entire content) is well represented by
Baym, G. *Lectures on Quantum Mechanics*. Benjamin, 1990.

A good example of an older book that may be useful is Merzbacher, E. *Quantum Mechanics*. J. Wiley, 1970.

For very modern topics with recent intense research activity (i.e. Quantum Computers - Quantum Information, Cryptography and Teleportation - Quantum Groups and Algebras - Quantum Hall Effect - issues of Quantum Mechanics and Gravity etc.) one could consult the Proceedings of an International Conference
Lim, S.C., et al. Ed. *Frontiers in Quantum Physics*. Springer, 1998.

Also the very good web-page of J. Preskill, *Lecture Notes on Quantum Information and Computation* at http://theory.caltech.edu/~preskill/ph229.

PHY 626 - Quantum Mechanics II

Constantia Alexandrou

Course Units: 4 / ECTS Credits: 7

1. Potential Scatering:
   Asymptotic states, scattering amplitude, the integral equation of potential scattering, Born series, cross sections, the Optical Theorem, partial waves, low energy resonances, analytic properties of the scattering amplitude.
2. Perturbation Theory:
   Stationary state perturbation theory, degenerate perturbation theory, time-dependent perturbation theory, first-order transitions, harmonic perturbations, second-order transitions.
3. Interaction of Radiation with Matter:
   Interaction Hamiltonian, absorption of light, spontaneous emission, the quantized radiation field, scattering of light, Raman scattering, the quantum vacuum.
4. Theory of Spin 1/2:
   Rotations in spin space, spin magnetic moment, spin resonance, the Pauli equation, relativistic theory, Lorentz transformation of spin, Dirac equation, Dirac hydrogen atom, hyperfine structure, the Lamb shift.
5. Atoms - Molecules:
   Two-electron atoms, Hartree, Fermi-Thomas and Hartree-Fock approximations, spin-orbit interaction, Zeeman effect, the Born-Oppenheimer method, the hydrogen molecule.
6. Path integrals in Quantum Mechanics:
   The classical action, the quantum-mechanical amplitude, the sum over paths, the free particle propagator, particle in a magnetic field, evaluation of path integrals, perturbation theory and path integrals, introduction to quantum electrodynamics.

Bobliography

G. Bayin, *Lectures of Quantum Mechanics*

A. Messiah, *Quantum Mechanics*

R.P. Feyman and A. R. Hibbs, *Quantum Mechanics and Path Integrals*

PHY 631 - Electromagnetism

Ioannis Vergados

Course Units: 4 / ECTS Credits: 7

Charges in fields, four-potential of a field, Lorentz force, electric and magnetic fields, gauge invariance, the electromagnetic field tensor, Lorentz transformation of the field, invariants of the field, the action of the electromagnetic field, the four-dimensional current vector, Maxwell equations, energy density and Poynting vector, constant fields, electrostatics and magnetostatics, electrostatic energy, dipole moments, magnetic moments, electromagnetic waves, characteristic vibrations of the field, Optics, diffraction, geometrical optics, the field of moving charges, the Lienard-Wiechert potentials, electromagnetic radiation, dipole radiation, radiation from a rapidly moving charge, spectral resolution of the radiation, scattering by free charges, electromagnetic field in continuous media.

Bibliography

L. Landau and E. Lifshitz. *The Classical Theory of Fields*.

W.K.H. Panofsky and M. Philips. *Classical Electricity and Magnetism.*

J. D. Jackson. *Classical Electromagnetism.*

PHY 641 - Statistical Physics

Georgios Archontis

Course Units: 4 / ECTS Credits: 7

From Quantum Mechanics to Statistical Mechanics, coherence-decoherence transition, from the wave function to the density matrix, Ensembles in Statistical Mechanics, the concept of entropy, the role of second law of Thermodynamics, the three basic ensembles (microcanonical, canonical, grand canonical), the partition function, the free energy Helmholtz and Gibbs, energy and density fluctuations, from the Schrodigner equation to the equation of state, the ideal gas in canonical and grand canonical ensemble, the ideal Fermi gas, Bose systems, photons and phonons, Bose-Einstein condensation, the principles of Classical Statistical Mechanics, phase space and the Liouville theorem, equipartition theorem, real gases, cluster and virial expansion, phase transitions, the Lee-Yang theory, the Ising model, critical phenomena, order parameter, correlation length, critical exponents, the scaling hypothesis, Goldstone excitations, the Ginzburg-Landau theory, critical and tricritical points, anomalous dimensions, the Kadanoff-Wilson theory, introduction to the renormalization group.

Bibliography

K. Huang. *Statistical Mechanics*.

L. Landau and E. Lifschitz. *Statistical Physics*.

R. P. Feynman. *Statistical Mechanics.*

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